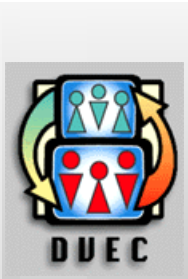

Image Processing and Image Filters in Java

by John F. McGowan, Ph.D.

Desktop Video Expert Center

NASA Ames Research Center

Introduction

- *Java is too slow for production image processing, but may offer advantages for prototyping and demonstration of image processing algorithms.*
- *Algorithm developers and scientists want a tool that allows them to concentrate on their work (math, science), not on the tool (C, Mathematica, Java).*

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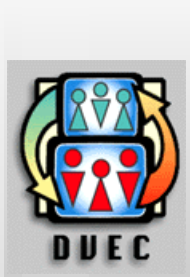

Image Filters in Java

- *Standard Java Wrapper for Image Processing Operations.*
- *java.awt.image Package*
  - *ImageFilter and RGBImage Filter classes*
  - *user derived filter classes*
- *In JDK 1.0*
- *Extended slightly in JDK 1.1*
- *Extended heavily in JDK 1.2 Beta*

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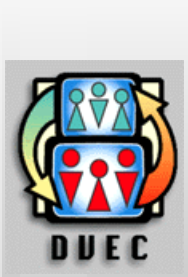

Image Filters and NASA

- *Astronomical Images*
  - *Planets*
  - *Sun and Stars*
- *Satellite Images*
- *Aerial Photographs*
- *Images from Simulations*
  - *Computational Fluid Dynamics*
  - *Solar Models*

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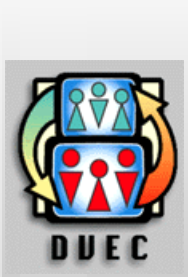

Image Filters and NASA

- *Edge Detection and Enhancement*
- *Image Segmentation*
- *Image Enhancement*
- *Image Analysis*
  - *e.g. Fourier Transforms*
- *Computer Vision*
- *Special Effects*

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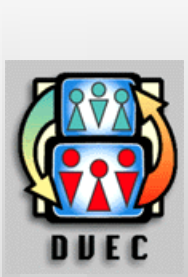


Outline of Talk

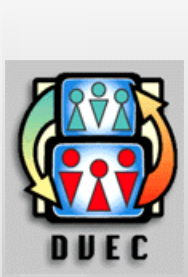
- *Desktop Video Expert Center*
- *Algorithm Development*
- *Image Filters and Image Processing in Java*
  - *Java Demo*
  - *How Java Images Work*
- *Conclusions*

Desktop Video Expert Center

- *Advanced Applications (R and D)*
- *Installation and Support of Videoconferencing Systems*
- *NASA Space Shuttle MBONE (Multicast Backbone) Broadcasts over Internet*
- *Evaluations of COTS Desktop Video Products*
- *http://zeus.arc.nasa.gov/*

DVEC Advanced Applications

- *Research and Evaluate Future Desktop Video and Networked Video Technologies.*
- *Develop New Technologies as Appropriate*
- *Software and Algorithm Development*
- *http://zeus.arc.nasa.gov/adv_apps.html*



Some Current Projects

- *DCTune: Perceptual Optimization of JPEG Images (with Vision Science and Technology Group)*
- *Studies of Wavelet, Fractal, and Other Leading Edge Video Coding Technologies*
  - *Smooth full-motion video over Internet?*
  - *Smooth full-motion video over telephone?*

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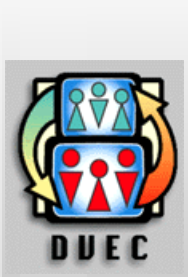
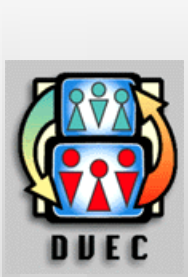


DCTune

- Patented NASA algorithm developed by Andrew B. Watson, Al Ahumada, and others with the Vision Science and Technology Group.
- Mathematica Prototype
- Converted to compiled C language binary executable
- http://vision.arc.nasa.gov/dctune1.1.html



Who am I?

- *Converted DCTune from Mathematica Prototype to portable ANSI C language version.*
- *Developed commercial MPEG-1 and MPEG-2 audio and video playback (decoder) software written in C for PC/Windows, Power Macintosh, and Unix platforms.*

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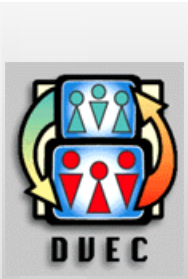
Who am I?

- *Image,Video, and Audio Compression Algorithms*
- *Ph.D. in Physics, University of Illinois at Urbana-Champaign*
  - *Maximum Likelihood Fitting Methods*
  - *Monte Carlo Simulations*
  - *Pattern Recognition*



Developing Algorithms

- *Cumbersome process*
- *Symbolic Manipulation Programs such as Mathematica, MATLAB, and MAPLE*
- *C/C++ Prototypes*
- *Pros and Cons to Both Methods*
- *Looking for Better Tools to Develop, Prototype and Demonstrate Algorithms*

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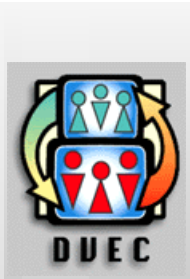
Traditional Algorithm Development

- *Proof of Concept in Software on Supercomputer, Mainframe or Unix Workstation*
- *Make Presentation or Publish a Paper*
- *Present Simple Demo*
  - *Grayscale Images*
  - *Very Slow*
- *Fund Further Development*

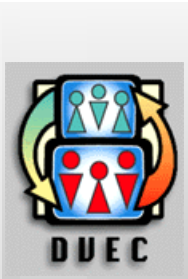


Traditional Algorithm Development

- *Design and Fabricate VLSI Chip Implementing the Algorithm*
- *Develop Better Software and **wait** for CPU's to get Fast Enough*
  - *Optimize the Software for Speed*
  - *Add Color Support*
  - *Support Arbitrary Picture Dimensions*

The New World

- *CPU Speeds Heading Above 500 MHz*
- *Algorithms Can Run on Desktop PC*
- *Very Fast Transition from Prototype to Product*
- *Argues for developing in C/C++ in PC/Windows environment.*
- *What can Java do?*



Mathematica Advantages

- *Symbolic manipulation*
- *Interpreted, Interactive*
- *High Level Mathematics*
  - *matrix multiplication m = a . b*
  - *special math functions*
  - *much more*
- *Built-In Graphical Rendering*
  - *Show[graphics]*

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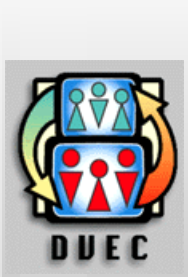

Mathematica Disadvantages

- *Slow*
- *Proprietary (Wolfram Research)*
- *Expensive ($2000)*
- *Requires Much Memory (300 MB)*
- *Arcane Syntax*
  - *e.g., MapThread[f, {{a,b,c},{ap,bp,cp}}]*
- *Learning Curve for C or other procedural language programmers*

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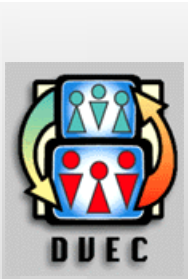

Other Symbolic Packages

- *MATLAB*
- *MAPLE*
- *REDUCE*
- *Probably similar advantages and disadvantages to Mathematica.*

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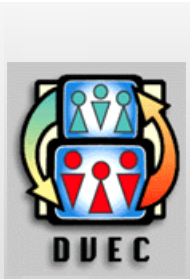
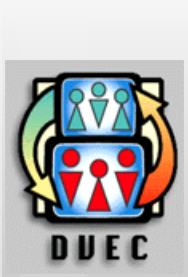


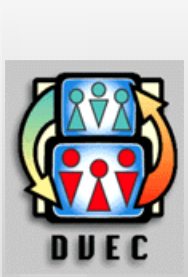
Many Symbolic Language Prototypes

- *Hard to reach mass audience.*
  - *For example, must own Mathematica*
- *Usually must convert to C, assembler, or an ASIC for a product.*
- *Usually must embed C version in platform OS or API*
  - *Video for Windows codec*
  - *QuickTime Component*



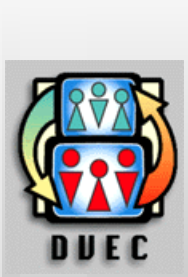
C/C++ Advantages

- *Fast/Compiled*
- *Executables are Free*
- *Unix GNU Compiler is Free*
- *Mac and PC Commercial Compilers*
- *De Facto Standard*
  - *Lingua Franca of Programmers*
  - *ANSI Standard*



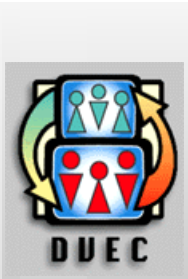
C/C++ Disadvantages

- No Built-In Graphics
  - Microsoft Windows (PC)
  - Mac Toolbox (MacOS)
  - X Windows (Unix)
  - Many Graphic File Formats (e.g. PPM)
- No High Level Mathematics
- No symbolic manipulation
- Porting Problems



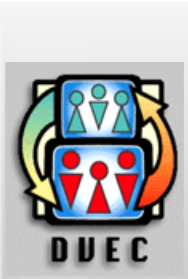
ANSI C Porting Problems

- *Byte-Order Dependent Code*
- *Gaps in Standard such as definition of bit shift by a negative number: a >> -1*
- *Bugs in Compilers. Video Compression Algorithms Stress Compilers.*
- *Complex Multimedia Algorithms Don't Always Port Easily*



Many C/C++ Prototypes

- *MPEG Software Simulation Group*
- *Berkeley MPEG Tools*
- *Wavelet Image Construction Kit*
- *Telenor H.263 Code*
- *Read/write sequences of still images (PPM, TGA etc.)*
- *Often Grayscale Only*
- *Much work to convert to graphical applications.*



Possible Java Advantages

- *Immediate Demonstration on Web*
  - *Administrators and Funding Agencies*
  - *Colleagues*
  - *Potential Customers and Licensors*
- *Built-In Graphics Rendering*
- *Image and ImageFilter Classes*
- *Portable*
- *Free*

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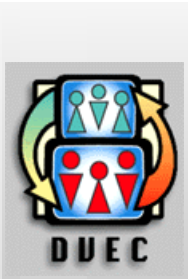


Possible Java Disadvantages

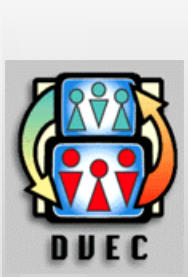
- *Slow (Interpreted Byte-code)*
- *No High Level Mathematics*
- *No symbolic manipulation*
- *Algorithm Must be Ported from Java to C to Create Product*
- *Not Portable*
- *Not Free*

Java Image Processing Demo

- *Demonstration of several standard edge enhancement and edge-detection algorithms.*
- *Moderately complex algorithms.*
- *A Real World Test of Java*
- *http://zeus.arc.nasa.gov/sword.html*

Motivation for Demo Algorithms

- *Study edge enhancement and edge detection algorithms for possible incorporation in a compression algorithm.*
- *Edge detection solves many problems: character recognition, flaw detection in silicon wafers, remote surveillance, and many other applications.*



Why Edge Detection for Compression?

- *Leading lossy video compression algorithms such as Discrete Cosine Transform and wavelets throw away or distort critical details at edges.*
- *Need to preserve sharp edges and lines for low bitrate image coding to look "natural" to a human viewer!*

Edges and Block DCT

JPEG Encoder in Paint Shop Pro

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Edges and Wavelets

Wavelet Image Construction Kit (Geoff Davis)

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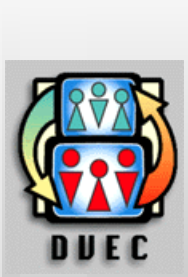
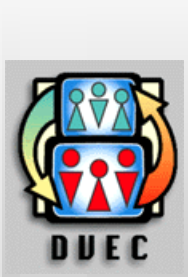


Demo Java Filter Applet

- *Java Filter Applet (using JDK 1.1.4)*
- *http://zeus.arc.nasa.gov/sword.html*
- *The Filter Applet works differently under different Web browsers and operating systems. :-(*
- *Fails completely for a few browsers and operating system combinations. :-(*



Images in Java

- *Poorly documented*
- *java.awt Package*
  - *Image class*
- *java.awt.image Package*
  - *ImageProducer, ImageConsumer, etc.*
- *Here is my educated guess how it works*

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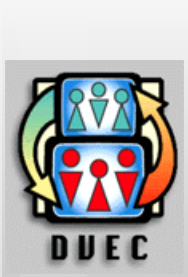

Images in Java

- *Image class*
- *ImageProducer interface*
- *ImageConsumer interface*
- *ImageFilter class (implements ImageConsumer interface)*
- *FilteredImageSource class (implements ImageProducer interface)*

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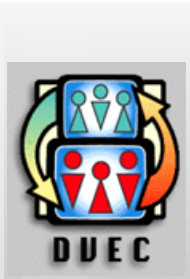
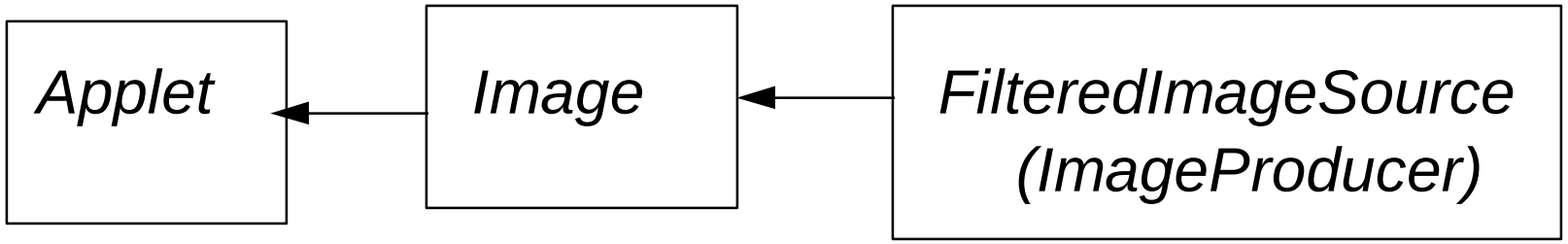


Java Graphics and Images

Applet::paint(Graphics g) { g.drawImage(image,...) }

image = createImage(FilteredImageSource)



Java Virtual Machine decides when to update data?

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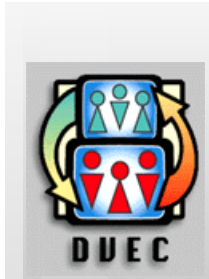
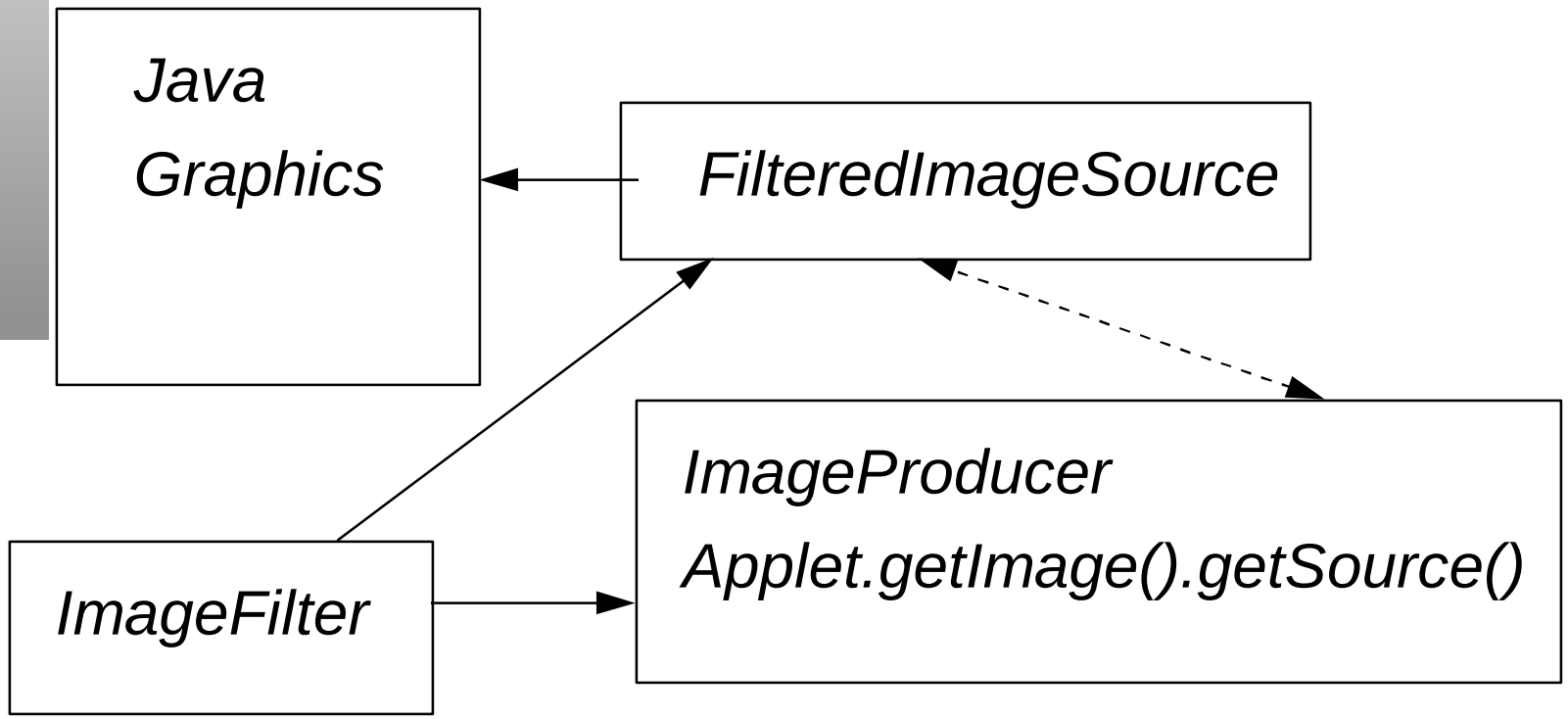


Java Image Processing



Java Virtual Machine decides when to update data?

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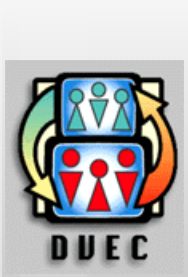

Image Class

- *Abstract class represents a **displayable image** in a platform-independent way.*
- *java.awt Package (NOT java.awt.image)*
- *Don't use constructor to create an Image*
  - *Applet.getImage() or createImage(producer)*
- *Image.getSource() returns the ImageProducer that produces the image data.*

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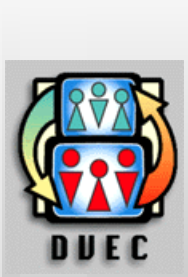
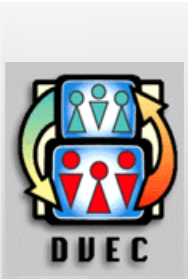


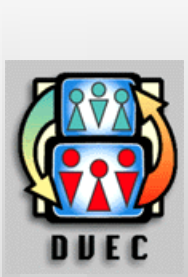
ImageProducer Interface

- *Defines the methods that any class that **produces image data** must define to enable communication with ImageConsumer classes.*
- *FilteredImageSource (java.awt.image) is an ImageProducer*
- *java.awt.image Package*



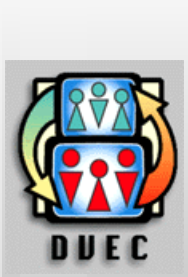
ImageProducer Interface

- *SOURCE of the image data*
- *not the IMAGE data*
- *file on hard disk*
- *URL of image (JPEG or GIF) on network*
- *a filter that processes an image*
  - *FilteredImageSource*



ImageConsumer Interface

- *Interface defines the methods necessary for a class that **consumes image data** to communicate with a class that produces image data, an ImageProducer.*
- *ImageFilters in Java implement the ImageConsumer Interface*
- *java.awt.image Package*



ImageFilter Class

- *java.awt.image Package*
- *Implement the ImageConsumer interface*
- *Represent a filter that performs an operation on an image*
- *Filter method run when the ImageFilter retrieves new data from an ImageProducer? (JVM?)*

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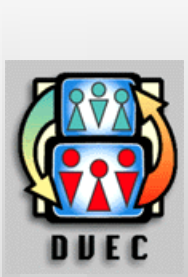

FilteredImageSource Class

- *Implements the ImageProducer Interface*
- *Constructor FilteredImageSource(ImageProducer orig, ImageFilter imgf)*
- *Image.getSource() retrieves the ImageProducer associated with a Java Image*

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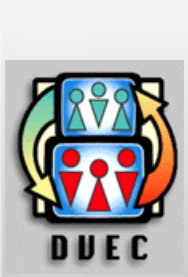

FilteredImageSource Class

- *Represents an object that takes data from another ImageProducer and applies a filter, represented by an ImageFilter class, and passes the filtered image on to another java object.*
- *Is itself an ImageProducer*

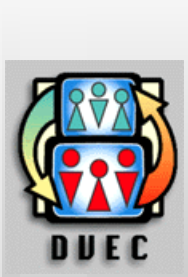

Image Events?

- *ImageProducers send "events" to ImageConsumers requesting image data.*
- *Images, ImageConsumers, ImageProducers maintain local buffers with copies of the image.*
- *Different Java Virtual Machines decide to send image events at different times.*

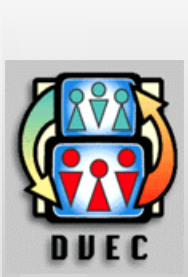

Image Events?

- *Standard does not define or products incorrectly implement the handshaking between ImageProducers, Consumers, and other graphics components.*
- *Updating of data in different objects occurs at different times with different Java Virtual Machines.*

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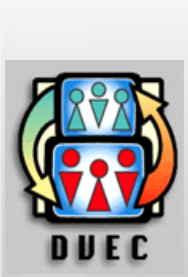
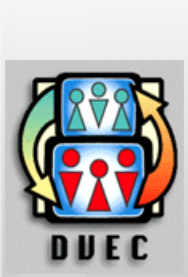


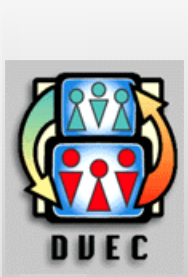
Conclusions

- *ImageFilter Class is a Great Idea.*
- *Java GUI easy to code.*
- *Slow, but slow is acceptable for a prototype.*
- *Portability is NOT THERE YET!*
  - *Biggest problem with Java ImageFilters.*
  - *Limits DEMONSTRATION of prototypes.*



Suggestions for Sun

- *Improve Portability*
  - *standardize image updating?*
- *More Speed (Interpreted Java)*
- *Java to Machine Code Compiler*
- *High Level Math Classes*
  - *Matrices and Matrix Operations*
  - *Special Functions (e.g. Error Function)*



Where to Get This Talk

- *http://zeus.arc.nasa.gov/sword.html*
  - *The Java Demo*
- *http://zeus.arc.nasa.gov/jugfeb18.pdf*
  - *Adobe PDF Format Version*
- *http://zeus.arc.nasa.gov/jugfeb18.ppt*
  - *Microsoft **Windows** Power Point Version*
- *http://zeus.arc.nasa.gov/*
  - *Desktop Video Expert Center Web Site*